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ANALYSIS AT AIR TRAFFIC DELAYS AT METROPOLITAN WASHINGTON AIRPO--ETC(U)
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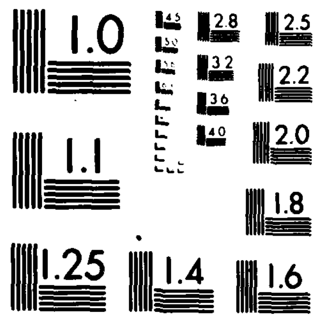

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ANALYSIS OF AIR TRAFFIC DELAYS AT METROPOLITAN WASHINGTON AIRPORTS

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September, 1977

Technical Supplement to
The Metropolitan Washington Airport Policy Analysis

Prepared for

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16. Abstract

The Federal Aviation Administration (FAA), as owner and operator of the Metropolitan Washington Airports, Washington National and Dulles International, is issuing a policy statement to guide development and operation of these facilities into the 1990's. The FAA's Metropolitan Washington Airport policy establishes a balance between a complex set of criteria which reflect transportation service, investment requirements, and environmental impacts.

Each of the policy alternatives considered has an associated disbenefit that is measured as delay to aircraft. Aircraft delays incur cost penalties to both aircraft operators and passengers. For aircraft operators these delays result in increased costs, for the passengers these delays represent lost time that may have been available for productive or leisure activities. Thus, in the evaluation of the merits of each policy alternative, the airside delay for each mode was determined.

This report presents the results of an analysis of the impact of policy alternatives on air traffic delays at the Metropolitan Washington Airports. A description of the range of policy options considered is contained in the appendix of the report.

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1.0 Introduction

The policy alternatives or modes presented in the Washington Metropolitan Airport Study - the Metro Study - have an associated disbenefit that is measured as delay to aircraft. These aircraft delays incur cost penalties to both aircraft operators and passengers. For aircraft operators these delays result in increased costs; for the passengers these delays represent lost time that may have been available for productive or leisure activities. Thus, in the evaluation of the merits of the modes in the Metro Study, the airside delay for each mode was determined. This appendix presents some of the key concepts involved in delay analyses and the approach used in determining the delays for the Metro Study.

2.0 Capacity/Delay Concepts

Airside delay is the delay experienced by aircraft as they move into and out of the airport system. This aircraft delay is a function of airport capacity and the demand at the airport. The demand, or operations, is the number of aircraft requests for landing or departure over some time interval; typical units of measure are operations per hour or annual operations.

Airport capacity is measured as the number of aircraft that the airport control system is capable of moving into and out of the aiport; a basic unit of measure is operations/hours.

Airport capacity is affected by such parameters as: types or mix of aircraft requesting service, runway configuration and use, weather conditions, arrival and departure airspace restrictions, types of control and communication available at the airport, etc. A set of rules and procedures, accounting for the nature of the parameters and constructed in the interests of safety, govern the ground controllers and the aircraft pilots in the movement of aircraft through the terminal area. Such rules and procedures include priority assignments to arriving or departing aircraft, runway occupancy rules, and separation standards. [1]

Aircraft experience delay in landing or departing when the time of movement exceeds some nominal time. The nominal movement time is the time required for an aircraft to move, at nominal velocities and accelerations, into and out of airport where that aircraft is the only user of the airport system. When other aircraft request service, the movement time for a given aircraft may be extended beyond the nominal, i.e., the aircraft may be delayed. Thus, a departing aircraft may be stopped at the runway threshold to permit an arriving aircraft to descend to that runway, roll, and exit the runway. As the demand increases the delays experienced by individual aircraft using the system tend to increase at a fast rate. These delay magnitudes, when used to evaluate an airport system, are usually expressed as an annual average or annual

total delay experienced by all aircraft users of the system.

The nature of the demand has a pronounced effect upon the magnitudes of delay that are experienced by aircraft. If each arriving or departing aircraft would move in an ordered pattern of time slots, then it might be expected that, with an hourly demand that is less than the maximum throughput rate or capacity, no delay would be experienced by the aircraft. However, aircraft request service, that is, desire to land or depart, in some random fashion. General experience has shown that the request for service has a Poisson distribution. With such a distribution it is possible for aircraft to experience delays when the demand is substantially less than the maximum or saturation capacity. Indeed, for such a Poisson distribution, when the demand is 15% less than the saturation capacity, the average aircraft delay at a single runway airport may be as high as 5.5 minutes. With such average delays individual aircraft would experience delays considerably in excess of the average value. If a number of such hourly average delays occur over a years' time, then the total delay experienced by all aircraft users would be high.

The probabilistic nature of the demand suggests that small decreases in capacity or small increases in demand could result in large changes in annual delay. That this is so is evident from the exponential nature of the delay as a function of capacity and demand with a Poisson-like distribution of demand.

The relationship is expressible as:

1) $$d_A = A\,P\,e^{a\,D_A/P}$$

d_A - annual delay

P - annual capacity

D_A - annual demand

A, a - constants

Typically, if an airport were operating at an annual demand to capacity ratio of about 0.92 then a 10% increase in demand would result in an increase in the average delay of about 27%. Conversely, a decrease in capacity may result in similarly dramatic increases in delay.

3.0 Delay Determinations for Metro Study

Impact of Metro Modes. Each of the policy alternatives or modes evaluated in the Metro Study present variations of aircraft mix and daily demand that could apply to the 1990 time period for the three major metropolitan Washington, D.C. airports. The 1990 time frame implies the use of equipments and operating procedures that would make the capacity of a given airport different from that in current use. As an example, the introduction of Metering and Spacing, the use of wake vortex measuring equipment, etc., will result in capacity changes. The variation of aircraft mix could result in a capacity change for each mode for each airport. The demand variation, coupled with the capacity for a given mode, could result in delay variation for each mode.

The airside delay determinations for this study then becomes that of (1) determining the airport capacity for each mode at each airport in the 1990 time frame and (2) computing the airside delay from the demand levels and the determined capacity for each mode.

Approach to Delay Computation. The general approach to determining airport delay is to compute an hourly capacity and, assuming a daily and yearly distribution of a given demand, compute an annual delay. Two generic techniques or models are currently available for this computation. The essential difference between these techniques is in the expression of capacity. One concept uses the saturation capacity, or maximum throughput rate, and the other concept employs a practical hourly capacity. The saturation capacity is the maximum number of aircraft that can be handled in an hour [2]. The practical hourly capacity is the number of aircraft that can be handled in one hour where the average delay to aircraft during that period is at some practical, acceptable level, e.g., 4 minutes, [3]. The latter model developed a Practical Annual Capacity (PANCAP) which, when combined with annual demand, yields an annual delay [4].

The PANCAP delay estimation model was developed in the early 1960's and continually modified to reflect real operating experiences. This model performs well in estimating delay [5]. However, it is somewhat difficult and cumbersome to factor in changes in key parameters that could affect capacity. The

saturation models, using refined computer-programmed, event simulation models, permit relatively simple determination of capacity from parameter changes. However, in its current state of development the model does not appear to be as effective a tool for delay determination as the PANCAP model. It is possible, however, to relate the saturation capacity to the practical hourly capacity and then use this basic value to compute delay employing the PANCAP technique. This logical approach was used in this study. That is, a saturation capacity value was obtained for each mode, converted to practical hourly capacity, and then the delay, using the demand level for each mode, was computed by the PANCAP model.

PMM Capacity Model. The saturation capacity was determined from a model recently developed for the FAA. This model, the PMM model, is available as an interactive computer program [6]. A typical printout is shown in figure 1. The program will exercise ATC configurations that incorporate advanced features that may be identified with a given time frame. As an example the G3 ATC configuration (line 2, figure 1) includes a wake vortex predictive system, metering and spacing, discrete address beacon system, and a microwave landing system. The program can exercise 51 runway configurations ranging from a single runway to a four runway configuration with various arrival and departure patterns and aircraft mixes. The aircraft mix (line 6, fig 1) is the percentage of a given class of aircraft in the total aircraft

*** AIRFIELD HOURLY CAPACITY MODEL ***
ON-LINE VERSION 1

DO YOU WANT A LISTING AND IMPLEMENTATION
SCHEDULE OF FUTURE ATC SYSTEMS?
no

ENTER PRESENT OR FUTURE ATC CONFIGURATION (P F1 F2 G3 H4)
p

ENTER VFR, IFR, OR LIFR
vfr

DO GA AIRCRAFT FLY A SHORT FINAL APPROACH?
y

ENTER RUNWAY USE DIAGRAM NUMBER (1 - 51)
1

ENTER AIRCRAFT MIX PERCENTAGE (CLASS A B C D)
FOR EACH PRINTED RUNWAY NUMBER
1-
5,15,55,25

ENTER ARRIVAL PERCENTAGE
67

ENTER TOUCH & GO PERCENTAGE
0

ENTER EXIT DISTANCES AND RUNWAY LENGTH
(FT) FOR EACH PRINTED RUNWAY NUMBER.
IDENTIFY HIGH SPEED EXITS WITH H AFTER DISTANCE.
ENTER W AFTER RUNWAY LENGTH TO IDENTIFY WET RUNWAY.
1-
3500,4500,5500,6500,10000

Figure 1

```
        *** INPUT SUMMARY ***
          ON-LINE VERSION 1

        P 0 ATC CONFIGURATION
        VFR  WEATHER
        DRY RUNWAY
        RUNWAY USE DIAGRAM #   1
        67 PERCENT ARRIVALS
         0 PERCENT TOUCH & GO
R/W     AIRCRAFT    MIX     TYPE
 #      %A   %B   %C   %D   OPN      EXIT LOCATIONS (FT)

 1       5.  15.  55.  25.  BOTH     3500    4500    5500    6500   10000



SINGLE RUNWAY MIXED OPERATIONS WITHOUT T & G

BATCH CAPACITY PROGRAM, VERSION 3
TO OBTAIN   67 PERCENT ARR, GAPS IN ARRIVAL STREAM MUST EXIST DURING    7
 PERCENT OF THE HOUR

             ***  AIRFIELD HOURLY RUNWAY CAPACITY   ***


             TOTAL =     51.3  ARRIVAL =    34.4  DEPARTURE =    16.9



DO YOU WISH TO PERFORM ANOTHER CALCULATION?
yes
```

Figure 1 (con't)

using the airport system. The listing of kinds of aircraft associated with each class is shown in figure 2. For a multiple runway configuration the mix would be expressed for each runway. For this airside delay analysis it was possible to obtain a saturation capacity for each mode for each of the three airports by successive use of this program.

PANCAP Delay Model. The saturation capacities so obtained were converted to hourly capacities usable in the PANCAP model. A computation sheet, illustrative of the technique, is shown in figure 3. This technique accounts for the effect of general aviation operations and the kinds of runway configurations that are used during parts of the year. As an example of the latter condition an intersecting runway configuration might have a different capacity when used in one direction, say, North-South, than when used in the opposite direction, South-North. The percentage of times that they are used are weighted against the capacities. These runway configurations, percent use, and associated capacities are weighted into a Weighted Hourly Capacity (line o, fig 3), which is converted into a PANCAP. The annual demand in each mode and the associated PANCAP are used to enter a delay vs Demand/PANCAP curve (figure 4) to determine delay for both VFR and IFR conditions. These delay values are weighted by percent VFR and IFR times to result in an annual delay for the airport.

Aircraft Classification	Types of Aircraft[a]
Class A	Single-engine propeller-driven aircraft (e.g., PA2, PA24, C150, BE23, C172/T41, AC20, C210)
Class B	Twin-engine propeller-driven aircraft (e.g., BE18, BE99, FA27, DH6, BE55/T42, AC6T, AC50, C310)
Class C	Four-engine propeller-driven aircraft and non-heavy jet aircraft[a] (e.g., B707/120B, B727, DC9, B737, BAC11, LR25, DC4, DC8-10, 20 series, G2/VC11, T33, T39, C500, F86, F101)
Class D	Heavy jet aircraft[b] (e.g., B747, DC10, L1011, A300, B707/300, VC10, Concorde, DC8-30, 40, 50, 60 series, C5A, C137, I162, C141, B52)

a. For aircraft type designation, see FAA Order No. 7340.1D.
b. Heavy jet aircraft are capable of 300,000 pounds or more whether or not they are operating at this weight during a particular phase of flight. (Reference: FAA Handbook 7110.8D with changes.)

FIGURE 2 AIRCRAFT CLASSIFICATION

AIRPORT ______________________________

RUN DESCRIPTION ______________________ YEAR ________

a Total Forecast Operations ____________

b Total Forecast Helicopter Operations ____________

c F (F = a-b) ____________

d % VFT Time (v) ____________

e % IFR Time (i) ____________

f Ratio of GA to total Operations (p) ____________

g V : $V = F[1 + i (\frac{p}{2(v+.5i)})]$

h I : $I = F[1 - v (\frac{p}{2(v+.5i)})]$

Configurations

		VFR				IFR			
i	Hourly Capacities (Saturation)								
j	% Time in Use								
k	.8 x i								
l	Arr/Dep Factor								
m	k x l								
n	Weighting Factor								
0	Weighted Hourly Capacity								
p	Peaking Factor								
q	VFR PANCAP					IFR PANCAP			
r	Demand (V) as % of VFR PANCAP					Demand (I) as % of IFR PANCAP			
s	VFR Delay					IFR Delay			

t :

u Total PANCAP: Annual Operations

v Total Delay: Aircraft Minutes

PANCAP Delay Model Computation Sheet

Figure 3

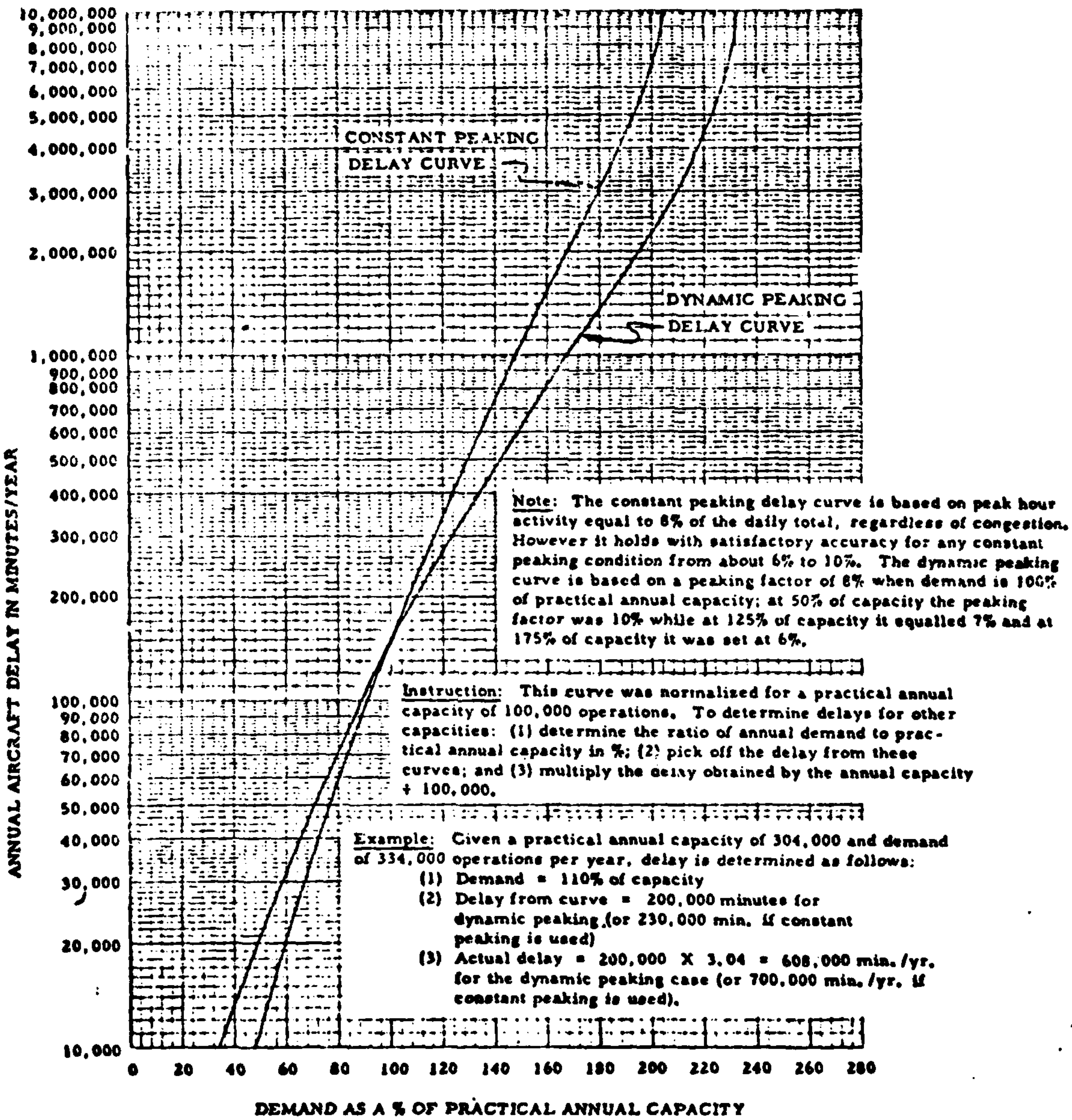

Figure 4 Annual Delay Curves

It is possible to express the delay vs Demand/PANCAP curves of figure 4 in mathematical form:

2) $d_A = c_1 P e^{a D_A / P}$

d_A - annual delay

D_A - annual delay

P - PANCAP

a, c_1 - constants

It is possible to extend the mathematical formulation even further. As an example, the mathematical formulation of annual delay from Weighted Hourly Capacity might be expressed as:

3) $d_A = k_1 (CV) \exp (K_2 \frac{DV}{CV}) = K_3 (CI) \exp (K_4 \frac{DI}{CI})$

C_{CV} - weighted hourly capacity, VTF

C_{CI} - weighted hourly capacity, IFR

D_{DV} - annual demand, VFR

D_{DI} - annual demand, IFR

k_1, k_2, k_3, k_4 - constants

Such matihematical formulations permit relatively simple computer programming.

Current Airport Profile. DCA [7] The runway layout consists of three (3) mutually intersecting runways with lengths of: 18/36: 6,870; 3/21: 4,724; and 15/33: 5,212 feet. An additional runway, 34 which is 1,500 feet long, is available for Short Takeoff and Landing (STOL) aircraft which are not considered in this report. Most air carrier operations, other than commuter flights, use runway 18/36, although during strong northwest wind conditions, runway 33 is used primarily for air carrier arrivals. Due to the limited length of the available runways and other considerations; e.g., terminal capacity, gate limitations, FAA restrictions, etc., only aircraft types 'A', 'B', and 'C' are allowed to use DCA, except in emergencies.

Because of the close proximity of prohibited areas and other restrictions, ILS equipment is installed only on runway 36. Thus, during extreme PVC weather, runway 36 alone may be active.

The exit taxiways for each runway and their distance from the threshold are:

Runway	Exit: Distance					
3	C:924	D:1,600	E:2,000	H:3,100		
15	K:1,500	J:2,000	M:3,600			
18	I:2,570	H:3,470	G:3,670	F:4,500	E:4,575	A:6,320
21	H:1,624	E:2,600	D:3,000	A:3,800		
33	M:1,612	J:3,100	K:3,200			
36	A:550	E:2,295	F:2,370	G:2,000	H:3,400	I:4,300

Operational utilization of runways, along with their percentage of use is as follows:

	Arrivals			Departures	
	VFR	IFR		VFR	IFR
R36	45.5%	65%		30%	30%
R33	18.2		North-	18	18
R3	1.3		bound	15	15
	65.0%			63%	63%
R18	26.2%	34%		20%	20%
R15	5.3	1	South-	16	16
R21	3.5		bound	1	1
	35.0%	35%		37%	37%

The above statistics apply to the basic runway configurations used, which are: north operation: 3/33/36, south operation: 15/18/21, and northwest operation: 33/36 where most arrivals use 33 and most departures use 36. As previously mentioned, extreme PVC weather may cause 36, or 18 only to be active, but this situation was estimated at only 1%, or at most 2% of the total operation time. Except for single runway operations, i.e., 18 or 36 only, and northwest operations, 33/36, there is no runway use diagram in the handbook which reflects the actual runway configurations which are used. The closest approximation to the actual usage was deemed to be runway use diagram no. 48 for two (2) intersecting runways, but it does not provide for arrivals and departures on both runways, nor for the restricted usage which actually occurs.

An existing operations demand maximum during IFR conditions limits the total scheduled or reserved operations to sixty (60) per hour, not including extra sections of the Eastern Airlines Shuttle between New York and Washington. Traditionally, this maximum has been allocated as follows: 40 air carrier plus twenty (20) GA aircraft; however, the recent experience has been a ratio of 70:30, rather than 67:33.

Current Airport Profile. BWI. [7] Baltimore (BWI) has three (3) major runways, which can accommodate most air carrier aircraft, and a short runway built for GA utilization during VFR conditions. These are 15R/33L, which is 9,500 feet in length, 10/28, which is 9,450 feet long, 4/22 at 6,000 feet, and the short GA parallel 15L/33R which is 3,010 feet long separated from 15R/33L by 3,625 feet. Type 'D' aircraft, e.g., B747, DC-10, L1011, etc., utilize the two longer runways, while type 'C' aircraft also use runway 4/22. Only type 'A' and 'B' aircraft can use the short runway, 15L/33R.

ILS approaches are permitted on runways 15R, 28, and 10, the latter serving Category II operations. Except for runway length limitations and, of course, wind conditions, there are no restrictions on runway usage due to obstructions, noise abatement, etc. Except for runway 4, each runway has runway-end taxiways;

however, in the capacity calculations, runway 4 is assumed to terminate at its last exit taxiway, which is only 365 feet from the actual end, reducing the "effective" runway length to 5,635 feet for the purpose of this study.

The exit taxiways for each runway, their letter designation, and their distances from the arrival threshold are:

Runway	Exit: Distance			
4	D:2,250	C:4,625		
10	G:1,465	E:5,470		
15R	H:2,025	F:3,425	E:6,070	T:8,380
15L	A:	B:1,960		
22	C:1,375	D:3,750		
28	E:3,980	G:7,985		
33L	T:1,120	E:3,430	F:6,075	H:7,475
33R	B:1,050	A:		

The operational configurations of runway usage are: east operation: 10,15R,15L,4; west operation: 22,28,33L, 33R; and south operations are conducted on 15R,15L, 22. Utilization percentages are 30%, 55%, and 15% respectively. In the west configuration, light aircraft, i.e., type 'A' and 'B', are frequently instructed by the local controller to "hold short of runway 28" when they arrive on runway 22.

Current Airport Profile. IAD. [7] IAD has two (2) staggered parallel runways, 1L/19R and 1R/19L (see IAD - Airport Taxi Chart), each 11,500 feet from each other, and runway 30/12 which is 10,000 feet long. Each runway is capable of handling the largest existing air carrier aircraft. In addition, portions of the taxiways parallel to runways 1R/19L and 30/12 have been designated general aviation (GA) VFR runways, although since IAD

does not currently operate even near maximum capacity, they are seldom actually used. It should be noted that IAD possesses enough land area to provide for the construction of an additional runway parallel to 30/12 of equal length and separated by about a mile southwest of the existing runway, augmenting its existing capacity significantly.

ILS equipment is currently operational on runways 19L, 19R, and 1R, the latter being certified to service Category II and IIIA approaches. Also, ILS equipment is scheduled to be installed on runways 1L and 12 during the third quarter of this fiscal year (FY '76). At that time, all possible PVC approaches will be accommodated.

Each of the parallel runways, 1L/19R and 1R/19L has three (3) high speed exit taxiways located at 3,148, 4,898, and 6,648 feet from each runway threshold. Runway 30/12 has two (2) high speed exit taxiways located as follows: R30: 3,436 and 5,936 feet; R12: 3,361 and 5,861 feet from their respective thresholds.

The basic operational runway configurations are:

Designation	Runways	% Used
North	1L,1R,30	55 - 60%
South	19L,19R,12	40 - 45%

During the time when these configurations are active, runway 30 is used for departures (north operation), and runway 12 is used for arrivals (south operation). Actual current practice is to direct GA arrivals to runway 1R/19L due to its proximity to the GA terminal area. There are no restrictions, because of obstructions, noise abatement, etc., to the utilization of any runways in the two (2) basic configurations.

<u>Procedures Used in This Study</u>. The approach described above was used in the airside delay computation. The dynamic delay curve of figure 4 was approximated by:

4) $0.92 \leq D_{A/P} < 1.4$

$$d_A = .08158\ P\ e^{2.857\ D_{A/P}}$$

$0.6 \leq D_{A/P} < .92$

$$d_A = .02778\ P\ e^{4.047\ D_{A/P}}$$

Data was generated for 35 modes for each of the three metropolitan Washington, D.C. airports: Washington National (DCA), Baltimore-Washington International (BWI), and Dulles International (IAD). The mode data was in the form illustrated in table 1 where two of the modes are shown for DCA. There is no corresponding WB class in the PMM capacity model. However, for DCA the

Mode \ Class	A	B	C	D	WB	Daily Demand
5	17.8	4.5	77.7	0	0	939
•						
•						
11	19.7	5.0	48.1	16.4	10.4	847

Mode Data
Table 1

D class as given in the mode data is part of the C class while the WB class corresponds to the PMM D class. Thus, the correlation is easily made as:

Mode Data		PMM Class
A	⟶	A
B	⟶	B
C	⟶	C
D	⟶	C
WB	⟶	D

The daily demand as given was translated into an annual demand for use in the PANCAP model delay computation.

The PMM model requires a breakout of mix per runway. As an example, an intersecting runway configuration requires the data broken out as shown in table 2.

RW # \ Class	A	B	C	D
1	0	2	84	14
2	86	14	0	0

Mix Breakout per Runway
Table 2

It was possible to do this for each airport from a knowledge of runway use. Information about runway use and percent of use was obtained from the literature and communication with airport

controllers at each airport. In similar fashion other pertinent information such as precent VFR and IFR times were obtained.

4.0 Results

The results of this analysis, the costs of aircraft delay are presented in the tables which follow. Average delay costs per minute are divided into aircraft costs and passenger costs to allow comparison from case to case (see Appendix A for a description of each case). Delay costs are also totaled for each airport and for the National, Dulles, and Baltimore Airport system, by case.

METROPOLITAN WASHINGTON AIRPORT POLICY ANALYSIS
AIRPORT DELAY COSTS

AIRPORT: DCA

CASE NUMBER	AIRCRAFT COST DOLLARS/MIN	PASSENGER COST DOLLARS/MIN	TOTAL COST PER MINUTE	ANNUAL DELAY COS ($000)
1	9.99	7.57	17.56	12645.55
2	11.36	8.52	19.88	13379.29
3	11.08	8.31	19.39	8168.87
4	10.77	8.08	18.85	7042.15
5	10.43	7.82	18.25	4856.57
6	9.98	7.48	17.46	3670.40
7	11.29	8.47	19.76	11740.02
8	10.79	8.09	18.89	7410.78
9	9.95	7.45	17.40	3077.35
10	11.72	8.90	20.63	13319.47
11	12.02	9.22	21.24	13296.92
12	12.36	9.59	21.95	13167.17
13	12.64	9.91	22.55	13074.53
14	11.26	8.57	19.83	7561.39
15	11.85	9.11	20.96	10875.68
16	12.01	9.39	21.40	8005.10
17	12.36	9.77	22.13	8201.74
18	10.65	8.16	18.80	3606.27
19	10.97	8.50	19.46	3302.82
20	11.49	9.07	20.56	3904.86
21	11.99	9.60	21.59	4167.30
22	12.61	9.90	22.51	12065.77
23	12.34	9.77	22.11	7319.18
24	11.93	9.55	21.48	3880.57
25	12.39	9.79	22.18	8024.55
26	11.29	8.47	19.76	12133.33
27	12.64	9.91	22.55	13137.67
28	12.38	9.79	22.17	7868.96
29	13.69	10.30	24.00	10277.59
30	15.14	11.92	27.06	9815.37
31	15.56	12.35	27.91	5430.56
32	16.11	12.97	29.08	2826.99

METROPOLITAN WASHINGTON AIRPORT POLICY ANALYSIS

AIRPORT DELAY COSTS

AIRPORT: BWI

CASE NUMBER	AIRCRAFT COST DOLLARS/MIN	PASSENGER COST DOLLARS/MIN	TOTAL COST PER MINUTE	ANNUAL DELAY COSTS ($000)
1	6.79	5.33	12.12	3174.45
2	9.28	7.23	16.51	3626.43
3	9.33	7.28	16.61	3570.10
4	9.42	7.37	16.79	3744.76
5	9.40	7.36	16.76	3572.71
6	9.52	7.46	16.98	4087.12
7	10.39	8.26	18.65	4489.35
8	9.42	7.37	16.79	3210.75
9	9.52	7.46	16.98	3328.11
10	8.67	6.63	15.30	3177.14
11	9.11	7.07	16.18	3278.99
12	9.10	7.06	16.16	3228.94
13	9.10	7.11	16.21	3125.73
14	9.35	7.31	16.66	3595.96
15	9.32	7.26	16.59	3498.65
16	9.27	7.21	16.48	3611.89
17	9.31	7.25	16.56	3628.92
18	9.42	7.35	16.77	3821.08
19	9.40	7.35	16.75	3671.50
20	9.23	7.20	16.43	3413.36
21	9.29	7.25	16.54	3478.29
22	10.26	8.17	18.44	4027.71
23	10.43	8.31	18.74	4811.43
24	9.33	7.17	16.50	2993.98
25	8.98	6.90	15.88	2994.11
26	10.40	8.26	18.66	4438.95
27	10.20	8.14	18.34	4085.66
28	10.38	8.27	18.65	4668.09
29	8.65	6.79	15.45	5266.05
30	8.24	6.48	14.71	4593.38
31	8.65	6.79	15.43	5477.86
32	8.75	6.89	15.64	5333.83

METROPOLITAN WASHINGTON AIRPORT POLICY ANALYSIS
AIRPORT DELAY COSTS

AIRPORT: IAD

CASE NUMBER	AIRCRAFT COST DOLLARS/MIN	PASSENGER COST DOLLARS/MIN	TOTAL COST PER MINUTE	ANNUAL DELAY C(($000)
1	8.47	6.97	15.43	1574.25
2	5.95	4.54	10.50	7925.18
3	7.08	5.53	12.60	9924.93
4	7.46	5.82	13.28	17735.16
5	8.22	6.50	14.72	17905.38
6	8.35	6.57	14.92	20616.57
7	7.39	5.84	13.22	10077.83
8	7.46	5.82	13.28	17502.55
9	8.35	6.57	14.92	25270.96
10	6.53	5.10	11.63	7477.75
11	6.06	4.74	10.80	5753.13
12	6.21	4.85	11.06	6253.78
13	6.11	4.78	10.89	5890.98
14	7.29	5.68	12.97	11284.68
15	7.16	5.56	12.72	10888.00
16	6.97	5.41	12.37	9756.24
17	6.84	5.31	12.15	10012.00
18	8.06	6.30	14.36	18238.34
19	8.09	6.29	14.38	18459.30
20	7.86	6.10	13.96	16868.36
21	7.65	5.93	13.58	15245.76
22	6.98	5.55	12.53	8958.20
23	7.34	5.71	13.05	12063.84
24	7.66	5.92	13.58	18714.99
25	6.68	5.14	11.82	10245.71
26	7.37	5.83	13.19	9975.53
27	6.86	5.46	12.31	8303.96
28	7.51	5.91	13.42	12626.02
29	5.95	4.58	10.53	8571.96
30	6.05	4.75	10.80	7865.80
31	6.62	5.16	11.78	12038.96
32	7.67	5.98	13.65	20160.53

METROPOLITAN WASHINGTON AIRPORT POLICY ANALYSIS
AIRPORT DELAYS

		Washington National Airport		Baltimore Washington Airport		Dulles Airport	
Scenario	Case	Total Annual Delay (Mins. 000)	Average Delay Per Operation (Mins)	Total Annual Delay (Mins. 000)	Average Delay Per Operation (Mins)	Total Annual Delay (Mins. 000)	Average Delay Per Operation. (Mins)
A	1	720.0	2.13	262.0	1.20	102.0	0.52
B	2	673.1	1.96	219.7	0.96	755.1	1.74
	3	421.3	1.58	215.0	0.98	787.4	1.74
	4	373.6	1.30	223.0	1.01	959.0	2.0
	5	266.1	1.03	213.2	0.98	1,216.0	2.4
Scenario #1	6	210.2	0.91	240.7	1.08	1,382.0	2.7
	7	594.0	1.79	240.7	1.05	762.1	1.7
	8	392.4	1.38	191.2	0.90	1,318.0	2.42
	9	176.9	0.77	196.0	0.92	1,694.0	3.34
	10	645.7	1.90	207.7	0.96	643.0	1.5
	11	626.0	1.86	202.6	0.94	532.7	1.31
Scenario #2	12	599.8	1.80	199.8	0.93	565.5	1.37
	13	579.8	1.76	192.8	0.91	541.0	1.32
	14	381.4	1.32	215.8	0.96	870.0	1.87
	15	519.0	1.63	210.9	0.97	856.2	1.85
	16	374.1	1.30	219.2	1.0	788.6	1.74
	17	370.7	1.31	219.2	1.0	824.1	1.84
	18	191.8	0.82	227.9	1.03	1,270.0	2.5
	19	169.7	0.62	219.2	1.0	1,284.1	2.52
Scenario #3	20	189.9	0.81	207.7	0.96	1,208.4	2.4
	21	193.0	0.82	210.3	1.01	1,122.7	2.26
	22	536.0	1.67	218.4	0.97	715.0	1.69
	23	331.0	1.21	256.8	1.12	924.5	1.99
	24	180.7	0.79	181.5	0.87	1,378.0	2.82
	25	361.8	1.28	188.6	0.89	866.9	1.97
Additional Policy Alternatives	26	613.9	1.83	237.9	1.04	756.2	1.69
	27	582.6	1.77	222.8	1.01	674.4	1.62
	28	354.9	1.26	250.3	1.10	941.0	2.05
	29	428.3	1.52	340.9	1.36	814.0	1.76
	30	362.7	1.35	312.2	1.28	728.2	1.66
	31	194.6	0.87	354.9	1.42	1,022.2	2.13
	32	97.2	0.66	341.0	1.37	1,476.7	2.81

A 1975 Base Case
B 1990 Base Case

APPENDIX A
METROPOLITAN WASHINGTON AIRPORT POLICY ANALYSIS
DESCRIPTION OF AIRPORT POLICY ALTERNATIVES

		Description		
Scenario	Case	Number Airline Quotas at DCA Per Hour 1/	Wide Body Aircraft Authorized AT DCA	Special Provisions
1975 Base Case	1	40	No	
1990 Base Case	2	40	No	
	3	35	No	
	4	30	No	
	5	25	No	
Scenario # 1	6	20	No	
	7	40	No	– No extra shuttle sections
	8	30	No	– No transfer of extra quotas to commuters
	9	20	No	– No transfer of extra quotas to commuters
	10	40	Yes	– 1 wide-body aircraft departure per hour average at DCA
Scenario # 2	11	40	Yes	– 2 wide-body aircraft departures per hour average at DCA
	12	40	Yes	– 3 wide-body aircraft departures per hour average at DCA
	13	40	Yes	– 4 wide-body aircraft departures per hour average at DCA
	14	30	Yes	– 1 wide-body aircraft departure per hour average at DCA
	15	30	Yes	– 2 wide-body aircraft departures per hour average at DCA
	16	30	Yes	– 3 wide-body aircraft departures per hour average at DCA
	17	30	Yes	– 4 wide-body aircraft departures per hour average at DCA
	18	20	Yes	– 1 wide-body aircraft departure per hour average at DCA
	19	20	Yes	– 2 wide-body aircraft departures per hour average at DCA
	20	20	Yes	– 3 wide-body aircraft departures per hour average at DCA
Scenario # 3	21	20	Yes	– 4 wide-body aircraft departures per hour average at DCA
	22	40	Yes	– 4 wide-body aircraft departures per hour average at DCA Also, no extra shuttle sections at DCA
	23	30	Yes	– 4 wide-body aircraft departures per hour average at DCA Also, no extra shuttle sections at DCA
	24	20	Yes	– 4 wide-body aircraft departures per hour average at DCA Also, no transfer of extra quotas to commuters
	25	30	Yes	– 4 wide-body aircraft departures per hour average at DCA Also, no transfer of extra quotas to commuters
	26	40	No	– 10:00 curfew on commercial jet traffic at DCA
	27	40	Yes	– 4 wide-body aircraft departures per hour average at DCA Also, 10:00 curfew on commercial jet traffic at DCA
	28	30	Yes	– 4 wide-body aircraft departures per hour average at DCA Also, 10:00 curfew on commercial jet traffic at DCA
Additional Policy Alternatives	29	40	No	– Commercial traffic only at DCA
	30	40	Yes	– 4 wide-body aircraft departures per hour average at DCA Also, commercial traffic only at DCA
	31	30	Yes	– 4 wide-body aircraft operations per hour average at DCA Also, commercial traffic only at DCA
	32	20	Yes	– 4 wide-body aircraft departures per hour average at DCA Also, commercial traffic only at DCA

1/ Except where otherwise noted, quotas at DCA surrendered by air carriers were reassigned to commuter operations.

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